PATENT SPECIFICATION

DRAWINGS ATTACHED

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Int. Cl.:—E 21 b 33/04

COMPLETE SPECIFICATION

Well Apparatus

We, CAMERON IRON WORKS, INC., of P.O. Box 1212, Houston, Texas, United States of America, a corporation organized and existing under the laws of the State of Texas, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to well apparatus generally, and, more particularly, to apparatus for use in completing oil and gas wells.

The present invention has as its aim the provision of improved wellhead apparatus for use in suspending casing from a wellhead located at an underwater level.

In accordance with this invention there is provided wellhead apparatus comprising a casing head having a bore therethrough, a seat within the bore, and a casing hanger, for suspending a casing, landable on the seat, the arrangement being such that when, during operation of the apparatus, the casing hanger is landed on said seat and a casing is suspended by the casing hanger, there are annular spaces defined between inner and outer walls above and below said seat; means providing flow passages connecting said annular spaces; and an assembly lowerable within the bore of the casing head and into the upper annular space to close said flow passages, said assembly including a first tubular body landable in said upper space when said assembly has been so lowered, a second tubular body, means releasably connecting the first and second bodies against vertical movement relative to one another, said second tubular body having means thereon releasably attachable to a running tool to permit the assembly to be lowered into the bore of the casing head upon manipulation of said running tool so as to land the first body in said upper annular space, a deformable seal ring disposed between oppositely facing shoulders on one side of the assembly, said connecting means being releasable upon landing of said first body and further manipulation of said running tool to permit said second body to be moved downwardly relative to the first body so as to deform said seal ring into sealing engagement with the wall opposite to said one side of the assembly, means for sealing between the other side of said assembly and the wall opposite thereto, and means on said assembly operable in response to manipulation of the running tool for anchoring said first body in its landed position within said bore and said second body in its lowered position relative to the fist body.

In order that the present invention may be better understood, a preferred embodiment of wellhead apparatus in accordance with it will now be described with reference to the accompanying drawings.

In the accompanying drawings, wherein like reference characters are used throughout to designate like parts:

Fig. 1 is an elevational view, partly in section, of the head of an offshore well located at an underwater level and having pressure control equipment connected to its upper end, the sectional part of such figure showing a mandrel having its upper end connected to a running tool, its lower end connected to the upper end of a casing, and landed on a seat within the bore of the wellhead for suspending a casing string within the well;

Fig. 2 is an enlarged half-sectional view of the upper end of the mandrel and the running tool shown in Fig. 1;

Fig. 3 is a half-sectional view similar to Fig. 2, but with the running tool released and removed from the mandrel and a seal assembly lowered onto and threadedly engaged with the mandrel by means of another running tool;

Fig. 4 is a view similar to Fig. 3, but wherein the running tool has been rotated so as to in turn rotate the second body of the seal assembly for lowering it with respect to the first body and thereby expanding the seal ring of the assembly into sealing engagement between

the first body and bore of the wellhead;

Fig. 5 is a cross-sectional view of the running tool and the second body of the seal assembly to which it is releasably attached, as seen along broken line 5—5 of Fig. 3;

Fig. 6 is a cross-sectional view similar to Fig. 5, but as seen along broken line 6—6 of Fig. 3; and

Fig. 7 is a vertical sectional view of the wellhead shown in Fig. 1, on a smaller scale and with the casing hanger shown in Fig. 1 as well as a second casing hanger suspending a second casing landed within the bore of the wellhead, and with the running tool for lowering the seal assembly of the second casing hanger releasably attached thereto, all in accordance with this invention.

With reference now to the drawings, the upper end of the well shown in Fig. 1 includes a conductor casing 10 which has been lowered into a bore hole 11 at the underwater level 12 of an offshore location. A base structure 13 secured about the upper end of conductor casing 10 rests on the level 12, and the conductor casing is anchored within the bore hole 11 by a column 14 of cement about at least a substantial portion of its length.

A casing head 15 is connected to the upper end of conductor casing 10 by means of a flange 16 having J-slots (not shown) for releasably attaching such flange to pins 17 projecting outwardly from the upper end of the conductor casing. The casing head is spaced from and connected to the flange 16 by guide wings 18 or the like which project downwardly from the flange to fit closely within the conductor casing and thereby center the casing head 15 with respect thereto.

A string of casing 19 is connected to the lower end of the bore 20 through the casing head for extension downwardly through conductor casing 10, and has its lower end anchored within the well by cement (not shown) as well known in the art. Pressure control equipment 21 releasably connected to the upper end of the casing head includes, from its lower end up, a remotely actuatable connector 22, one or more blowout preventers 23, and a riser pipe 24 which extends upwardly to the water level (not shown).

Generally, these parts of the pressure control equipment form a continuous bore of substantially the same diameter as the upper end of the bore 20 in the casing head 15, whereby various tools which can be lowered into the casing head bore may be passed through the pressure control equipment. The details of the connector 22, blowout preventer 23, and the riser pipe 24 as well as the parts for connecting them to one another form no part of the present invention, and therefore are not described in detail. It is merely sufficient to note that the pressure control equipment including the connector 22 is lowerable into and remotely attachable to the upper end of the casing head 15 after such casing head has been positioned as shown in Fig. 1. In this manner, one or more casing strings may then be lowered into and landed within the casing head for suspension within the well, as will be described to follow, while maintaining pressure control over the well.

As shown in Fig. 1, a casing hanger 25 having a casing 25a suspended from its lower end has been lowered through the pressure control equipment 21 and a seat 27 (see Fig. 2) thereon landed on a seat 26 in the bore 20 of the casing head. With the casing hanger 25 so landed, the casing 25a is suspended within the casing 19 in spaced relation thereto to provide an annulus thereabout which extends upwardly to the seat 26 in the bore 20, being defined immediately below the seat by the casing hanger, constituting an inner wall and the casing head, constituting the outer wall. This annulus is connected to an upper annular space likewise defined by the casing hanger and casing head above the seat and hence to the bore of the casing head, by means of flow passages 28 formed vertically within the casing hanger 25.

The casing hanger 25 comprises a mandrel having an upper portion 29 which is relieved to provide an upwardly facing shoulder 30 above the conical seat 27. As best shown in Fig. 2, a running tool 31 is releasably connected to the upper portion 29 of the mandrel and is suspended from the lower end of a casing string 32, whereby the mandrel with the casing 25a suspended from it may be lowered into the well and the mandrel landed within the bore of the casing head, as previously described.

Again as best shown in Fig. 2, the running tool 31 includes a tubular body 33 having internal threads 34 about its upper end for connection with threads 34a about the lower end of the lowermost joint of casing string 32. There are also internal threads 35 about the lower end of the running tool body 33 for releasable connection with threads 35a about the upper portion 29 of mandrel 25. When these latter threads are made up, an O-ring 33a on the inner circumference of the body 33 is sealably engaged with the upper portion 29 of the mandrel above the threads 35. The outer circumference of the body 33 fits relatively closely within casing head bore 20 as well as the bore of the pressure control equipment 21, but is slotted, as at 33b, to facilitate its being lowered through the bores and to permit upward circulation of returns during cementing.

The casing string 32 extends upwardly to the water level so that cement may be pumped downwardly through it and the casing 25a suspended from the mandrel 25, and then upwardly within the annulus about the casing 25a. During the cementing operation, returns are taken upwardly through the annulus between the casings 19 and 25a from which they

pass into the annulus below the seat 26 and through the mandrel flow passages 28 into the annulus between the mandrel and casing head above the seat and thence into the bores of the casing head and pressure control equipment for flow upwardly to the water level.

The threads of the couplings of casing string 32, including threads 34a, are right-hand threads. However, threads 35 and 35a are left-hand threads so that they may be disengaged by right-hand turning of the casing string 32. In this manner, upon completion of the cementing operation, the running tool is detached and withdrawn from the casing head and pressure control equipment, and a seal assembly 36 is lowered through the conductor and onto the mandrel 25 in the bore 20 for closing the flow passages 28. As shown in Fig. 3, the seal assembly is lowered by means of a running tool 37 suspended from the lower end of a drill string 37a.

As shown in Fig. 3, the seal assembly is comprised of a pair of tubular bodies 38 and 39 which are made up with one another by means of threads 40 disposed about the upper end of the body 38 and threads 40a disposed about an intermediate portion of the body 39. The first body 38 has threads 41a about its lower end for making up with threads 41 about the mandrel 25 intermediate the running tool threads 35a of the mandrel and the seat 27 thereabout. More particularly, the threads 41 on the mandrel are arranged radially outwardly of the threads 35a so that the threads 41a on the seal assembly body are free to move downwardly over the threads 35a into position for engagement with the threads 41 on the mandrel. As can be seen from Fig. 3, the seal assembly is guided into position for making up with the mandrel by means of its relatively close fit within the bore 20 of the casing head 15.

The upper end of the second body 39 of the seal assembly is releasably attached to the running tool 37 by means of pins 42 which project outwardly from the body 43 of the running tool for fitting within annular grooves 44 about the inner circumference of the upper end of body 39. As will be described to follow, this releasable attachment of the running tool to the body 39 of the seal assembly not only permits the entire assembly to be lowered onto the casing hanger, but also permits it to be rotated for anchoring thereto by the engagement of threads 41. Thus, the seal assembly bodies 38 and 39 are releasably connected against rotation relative to one another by means of one or more shear pins 45, so that right-hand torque transmitted to the running tool body 43 by the drill string 37a will be transmitted to the body 39 and thus to the body 38 for making up the threads 41a on the body 38 with the threads 41 on the mandrel 25.

There is a tapered shoulder 46 on the inner circumference of the seal assembly body 38 which seats upon a similarly shaped shoulder 47 on the upper end of the upper portion 29 of mandrel 25 so as to limit the threaded engagement of the body 38 with the mandrel. During this makeup of the seal assembly with the mandrel, an O-ring 48 moves into slidable sealing engagement with the upper portion of the mandrel above the threads 35a. There is an additional seal ring 48a on the tapered shoulder 46 of the body 38 for engaging the shoulder 47 of the mandrel to provide a further seal between these two members when the body 38 is fully made up with the mandrel so as to anchor the seal assembly thereto.

A deformable seal ring 50 surrounds the body 38 and is carried on an upwardly facing shoulder 51 about its outer side. The upper end of this seal ring is disposed opposite a downwardly facing shoulder 52 on the lower end of body 39. In the relative positions of the bodies 38 and 39 when they are connected by shear pin 45, as shown in Fig. 3, the seal ring 50 is relaxed so that its outer circumference is spaced radially inwardly from the bore 20 of the casing head 15. Thus, the seal assembly is free to move through the pressure control equipment and bore of the casing head into the position of Fig. 3.

However, when the body 38 of the seal assembly has been made up with the mandrel 25, and further makeup is limited by engagement of the shoulders on the body and mandrel, continued right-hand torque imparted to the body 39 will cause the pin 45 to be sheared. As a result, the body 39 will be further threadedly engaged with the body 38, thereby causing the shoulder 52 on the lower end of body 39 to move downwardly against seal ring 50. Thus, the seal ring will be expanded radially to sealably engage between the body 38 and the bore 20 of the casing head, as shown in Fig. 4. At this time, the flow passages 28 in the mandrel will be closed off, assuming that the seal between the body 38 and the mandrel 25 as well as the seal between the body 38 and the bore of the casing head will hold the desired pressure.

This ability of the seal assembly to hold pressure is preferably tested by a method which includes the use of the running tool 37. Thus, the body 43 of the running tool carries a cup type packing 53 thereabout for sealing between such body and the inner circumference of the mandrel 25, as shown in Fig. 3. Test pressure may then be admitted to the annular space between the drill string 37a for the running tool and the bore of the casing head as well as the bore of the pressure control equipment thereabove up to the closed rams of the preventer, so as to determine the pressure holding capacity of the seal assembly.

If the assembly holds the desired test pressure, the running tool 37 is released therefrom and withdrawn from the pressure control

equipment above the casing head. On the other hand, if the seal assembly does not test properly the running tool for it is manipulated to release the assembly from the mandrel and raise it from within the control equipment. For this purpose, and as above described, the running tool is capable of imparting either right or left-hand torque to the body 39 of the seal assembly. Since right-hand torque is used in making up the connection between the seal assembly and the mandrel and then actuating the seal ring 50, it is obvious that the seal ring 50 would be relaxed and that the body 38 of the seal assembly will be detached from the mandrel 25 by left-hand torque. As this left-hand torque is applied to the body 39 through the running tool 37, the threads 40a of the body 39 will move upwardly along the threads 40 of the body 38 until the body 39 reaches approximately the position shown in Fig. 3, at which time the seal ring 50 will again be relaxed. During this initial left-hand turning of the body 39, there is considerable friction between the body 38 of the seal assembly and both the mandrel 25 and the bore of the casing head by way of the seal ring 50 which opposes movement of threads 41a.

As shown in Figs. 3 and 4, a split spring 54 is disposed about the body 38 of the seal assembly prtially within a groove 55. Normally, this spring extends radially outwardly of the outer circumference of the body 38, as shown in Fig. 3, so as to also be disposed partially within an oppositely facing groove 56a about the inner circumference of body 39, whereby such spring bridges the separation between the bodies.

For the purpose of completely detaching body 38 from body 39, should this become necessary, one or more screws 56 may be removed and a tool inserted to contact the spring 54 wholly into the groove 55 to permit body 39 to be unscrewed upwardly therepast. During setting of the seal assembly in the well, as bodies 38 and 39 are being threaded together to energize the seal ring 50, spring 54 is carried into groove 55, as shown in Fig. 4, by a tapered surface on the upper side of the groove in the body 39.

When the body 39 is moved upwardly with respect to body 38, the spring 54 moves outwardly into a position to be engaged by shoulder 56a on the body 39 adjacent the lower edge of screw 56, as shown in Fig. 3. This, of course, prevents further unthreading of the body 39 with respect to body 38, so that coninued left-hand rotation of the body 39 will be transmitted to the body 38 so as to detach threads 41 and 41a and thus release the seal assembly 36 from the mandrel 25. Threads 41 and 41a are relatively easy running compared with the threads connecting the joints of the drill string 37a. Thus, the normal tendency will be to detach these threads rather than disconnect a portion of the drill string. When the seal assembly is detached from the mandrel 25, it can be raised from within the bore of the wellhead and the pressure control equipment 21 by means of the running tool 37.

As shown in Figs. 5 and 6, there are four circumferentially spaced-apart annular grooves 44 in the upper end of the seal assembly body 39. These annular grooves are spaced apart by means of arcuate inserts 58 held within the grooves by screws 59 or the like (see Fig. 5) and providing abutments on their opposite sides. One end of each annular groove 44 connects with an axial groove 60 which, as best shown in Fig. 4, extends to the upper end of body 39. The pins 42 carried by the body 43 of the running tool are free to pass vertically into and out of the axial slots 60.

The running tool 37 also includes a series of balls 61 which are carried by the body 43 and urged by springs 62 into a retained position within sockets 62a in which they project slightly from the outer circumference of the body 43, as shown in Figs. 4, 5 and 6. More particularly, these balls engage with an abutment at one end of the groove 44 when the pins 42 are engaged against an abutment at the opposite end of such groove, so as to retain the pins 42 in the positions shown in Figs. 5 and 6, wherein they are disposed beneath the upper side of the groove 44, and thus in direct supporting position beneath a ledge on the upper end of the body 39.

In the initial attachment of the running tool to the seal assembly, the body 43 is oriented into a position in which the pins 42 are free to move axially into the slots 60, the spring-pressed balls 61 being urged inwardly. The seal assembly is then turned so as to move pins 42 into engagement with an abutment on one side of the adjacent insert 58. The balls 61 will at the same time be moved over the inserts 58 into the position shown in Figs. 5 and 6. With the seal assembly thus attached to the running tool 37, the drill string 37a is lowered through the pressure control equipment to lower the seal assembly onto the mandrel.

After the seal assembly is so lowered, right-hand torque is imparted to the running tool causing the balls 61 to retract and the pins 42 to engage the other ends of the grooves 44 and thereby impart right-hand torque to the seal assembly. After the seal assembly has been attached to the mandrel 25, seal ring 50 energized and the seals tested as described above, and assuming that the seal assembly has been found to hold a desired test pressure, the running tool 37 may be withdrawn.

If the test shows that the seal assembly does not hold a desired pressure, the running tool is rotated in a left-hand direction so as to move the pins 42 into abutment with the opposite ends of the grooves 44 in the position of Figs. 5 and 6. Continued left-hand rotation of the running tool will then impart left-hand torque

to the body 39 which, as previously described, results in relaxing of the seal ring 50 and detachment of the body 38 from the mandrel. Thus, the seal assembly is securely supported from the running tool as it is raised from within the bore of the wellhead and the conductor, the balls 61 serving to prevent accidental rotation of the seal assembly relative to the running tool.

As shown in Fig. 7, after actuation of the seal assembly 36 to close off the flow passages through the mandrel 25, another casing 63 may be suspended within the well concentrically within casing 25a by means of a mandrel type casing hanger 63a lowered onto and landed upon an upwardly facing conical seat 64 on the upper inner circumference of body 38. This mandrel 63a is similar in many respects to the mandrel 25. Thus, it has flow passages (not shown) for connecting the annular space between the casings 25a and 63 beneath the seat 64 with the bore of the wellhead above such seat, so that in the cementing of the oil string 63 within the well bore, cement may be conducted downwardly through the casing 63 and up the annular space about it, with returns being taken through the flow passages in the mandrel 63a.

These flow passages are then closed, similarly to the flow passages 28 through mandrel 25, by a seal assembly 65 lowered onto and anchored with respect to the mandrel 63a in much the same manner as the seal assembly 36 above described. Thus, as shown in Fig. 7, the seal assembly is so lowered by means of a running tool 66, which is similar in many respects to the running tool 37, so as to permit right and left-hand rotation to be imparted to the seal assembly.

As can be seen from Fig. 7, the seal assembly 65 seals across the annular space between the mandrel 63a and the bore 20 of the casing head. The seal assembly 65 differs from the seal assembly 36 in that it additionally includes a set of slips 67 for anchoring it within the bore of the casinghead, and thereby holding both the mandrel 63a and the mandrel 25 down within the casing head. More particularly, these slips 67 are so arranged and constructed as to be automatically urged into engagement with the bore of the wellhead as the upper body 65a of the seal assembly 65 is moved downwardly with respect to the lower body 65b thereof in the expansion of the seal ring 65c, disposed on the outer side thereof, into sealing engagement with the bore of the casing head. The means for sealing between the inner side of the assembly and the mandrel 63*a* is an O-ring 70 on the inner circumference of the lower body 65*b*.

Upon landing of the casing hanger 63a and successful actuation of the seal assembly 65 so as to close off the flow passages through the mandrel 63a, the running tool 66 is released from the seal assembly and withdrawn from within the conductor above the casing head. At this time, the well may be completed by the running of tubing and the setting of a Christmas tree, all in a manner which does not form part of the present invention.

WHAT WE CLAIM IS:—

1) Wellhead apparatus, comprising a casing head having a bore therethrough, a seat within the bore, and a casing hanger, for suspending a casing, landable on the seat, the arrangement being such that when, during operation of the apparatus, the casing hanger is landed on said seat and a casing is suspended by the casing hanger, there are annular spaces defined between inner and outer walls above and below said seat; means providing flow passages connecting said annular spaces; and an assembly lowerable within the bore of the casing head and into the upper annular space to close said flow passages, said assembly including a first tubular body landable in said upper space when said assembly has been so lowered, a second tubular body, means releasably connecting the first and second bodies against vertical movement relative to one another, said second tubular body having means thereon releasably attachable to a running tool to permit the assembly to be lowered into the bore of the casing head upon manipulation of said running tool so as to land the first body in said upper annular space, a deformable seal ring disposed between oppositely facing shoulders on one side of the assembly, said connecting means being releasable upon landing of said first body and further manipulation of said running tool to permit said second body to be moved downwardly relative to the first body so as to deform said seal ring into sealing engagement with the wall opposite to said one side of the assembly, means for sealing between the other side of said assembly and the wall opposite thereto, and means on said assembly operable in response to manipulation of the running tool for anchoring said first body in its landed position within said bore and said second body in its lowered position relative to the first body.

2) Wellhead apparatus according to Claim 1, wherein the anchoring means is releasable in response to still further manipulation of said running tool so as to permit said second body to be moved upwardly relative to the first body, whereby said seal ring may retract from its deformed position, and so as to permit said first body to be raised from its landed position.

3) Wellhead apparatus according to Claim 2, including means for supporting said first body from the second body for upward movement therewith as said second body is moved upwardly upon release of said anchoring means, to permit said first body to be raised from within the bore with said second body by means of said running tool.

4) Wellhead apparatus according to any preceding Claim wherein said anchoring means

includes parts on the outer side of the assembly movable into locking engagement with the bore of the casing head upon deformation of said seal ring due to downward movement of said second body relative to the first body.

5) Wellhead apparatus according to any preceding claim wherein said means releasably connecting the first and second bodies comprises a shear pin.

6) Wellhead apparatus according to any preceding Claim, wherein said one side of the assembly is said outer side thereof.

7) Wellhead apparatus according to any preceding Claim, wherein said annular spaces above and below said seat are both defined between said casing hanger, constituting the inner walls, and said casing head, constituting the outer walls.

8) Wellhead apparatus according to any preceding Claim, wherein said oppositely facing shoulders are formed on the first and second tubular bodies, respectively.

9) Wellhead apparatus according to any preceding Claim, wherein the anchoring means includes means on the first body adapted to anchor the first body to the casing hanger.

10) Wellhead apparatus according to Claim 9, wherein the means on the first body for anchoring it to the casing hanger comprises threads for engaging with threads on said casing hanger when said assembly is lowered into the upper annular space, wherein means are provided for limiting such threaded engagement to locate said first body against further downward movement relative to the casing hanger, and wherein the first and second bodies are threadedly engaged with one another and connected against relative rotation to permit the threads on the first body to be engaged with those on the casing hanger in response to rotation of the second body by said running tool, said connection of the first and second bodies being releasable upon said limited threaded engagement of the first body with the casing hanger and in response to continued rotation of the second body.

11) Wellhead apparatus according to Claim 10, wherein the casing hanger is a tubular mandrel having an upper portion which is relieved above the seat about its outer side, and the threads on the first body are engageable with threads on the upper mandrel portion.

12) Wellhead apparatus according to Claim 10 or Claim 11, characterized in additional threads on the casing hanger of opposite hand to the threads thereon to which the first body is connected, said additional threads being releasably attachable to a running tool for lowering the casing hanger into landed position on the seat.

13) Wellhead apparatus according to Claim 12, wherein the first mentioned and additional threads on the casing hanger are disposed about longitudinally spaced-apart external portions thereof.

14) Wellhead apparatus according to any one of Claims 10—13, wherein the second body of said assembly has at least one annular groove thereabout with abutments at each end and an axial groove connecting the upper end of the second body with the annular groove adjacent one of said abutments, and said running tool has a cylindrical portion adapted to fit concentrically of the assembly, a pin on the cylindrical portion of the tool movable downwardly through the axial groove and rotatably within the annular groove for selectively engaging with said abutments in order to impart rotation to the assembly, and a spring-pressed ball on said cylindrical portion of the tool spaced angularly from the pin for engaging with one of said abutments when said pin is disposed with the annular groove to one side of the axial groove.

15) Wellhead apparatus according to Claim 10 when dependent upon at least Claims 5 and 6, further including oppositely facing grooves about the outer side of the first body and inner side of the second body, respectively, and a split spring partially within each groove to bridge the separation between the bodies, the upper end of the groove about the second body having a cam surface for radially compressing the spring into the groove about the first body upon shearing of said shear pin and further threaded engagement of the second body with the first body. so as to move the shoulder on said second body toward the shoulder on the first body and thereby deform said seal ring radially outwardly between said shoulders, said second body being movable upwardly relative to the first body to return the groove thereabout to a position opposite the groove about the first body so as to permit the spring to move back outwardly into a position bridging the separation between the bodies, and the lower end of the grove about the second body being engageable with the spring so as to prevent further upward movement of the second body relative to said first body.

16) Wellhead apparatus, substantially as hereinbefore described with reference to the accompanying drawings.

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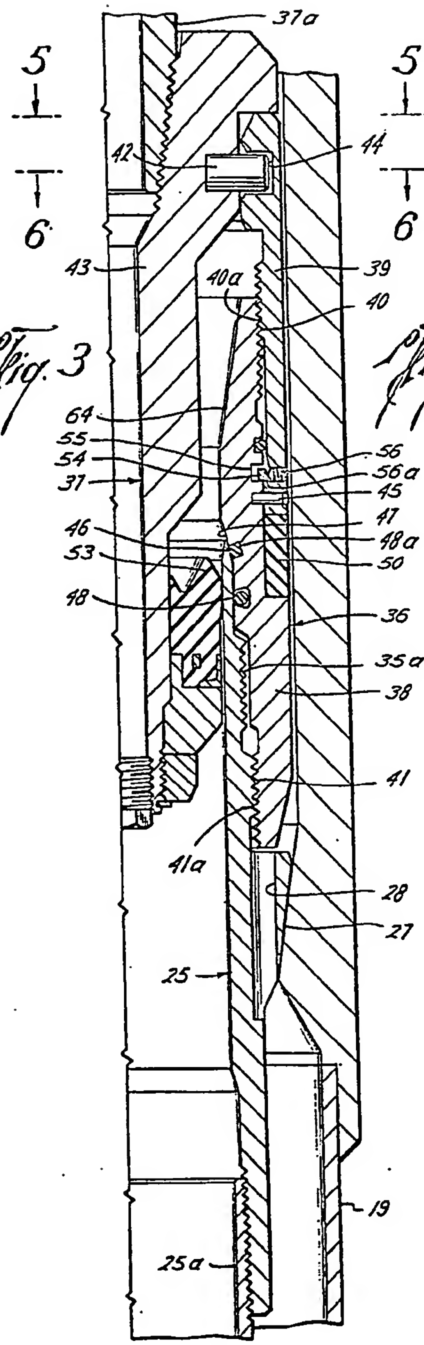
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Fig. 3

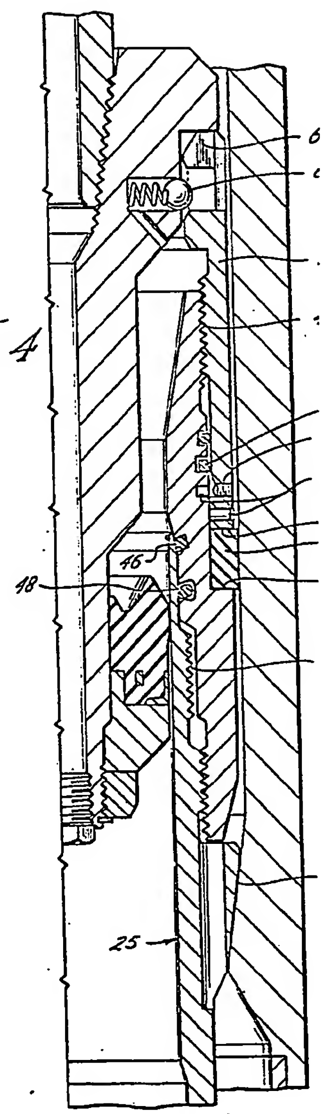
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Fig. 4

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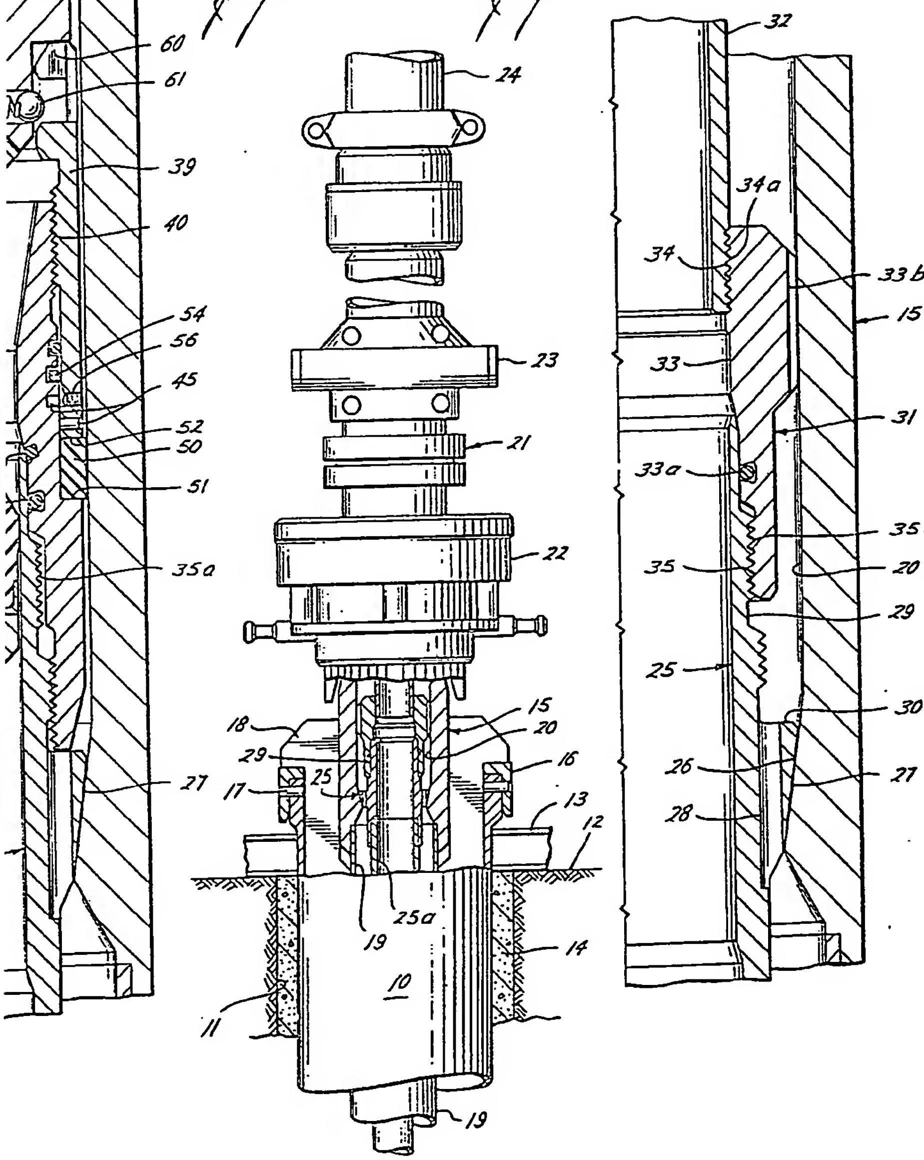
Sheet 1

Fig. 1 Fig. 2



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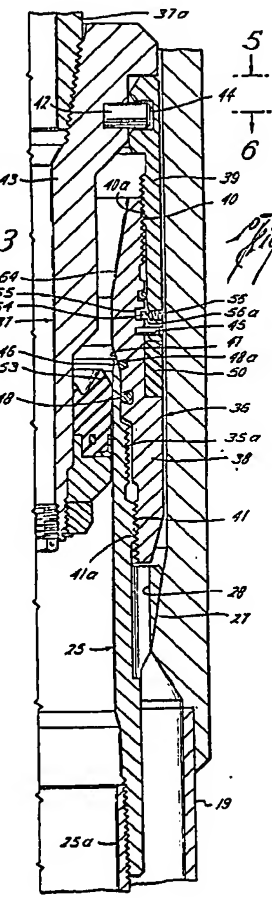


Fig. 3

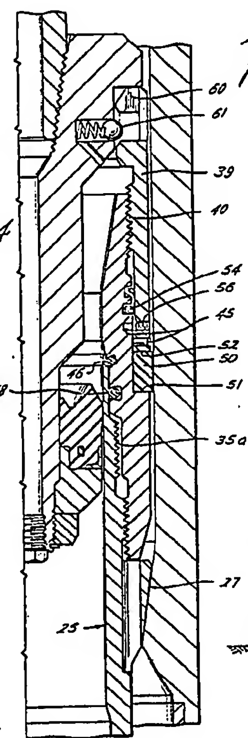


Fig. 4

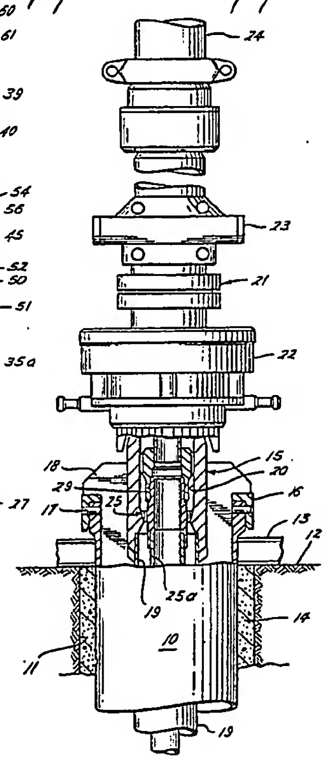


Fig. 1

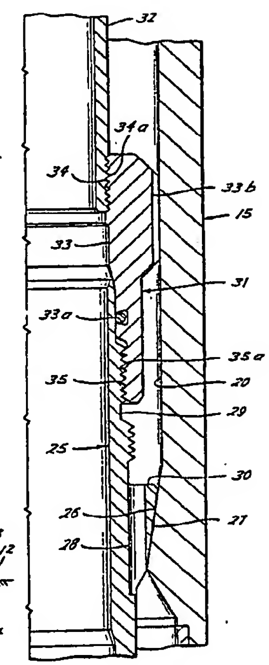


Fig. 2

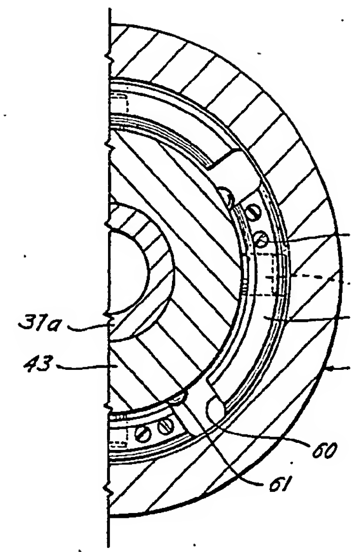
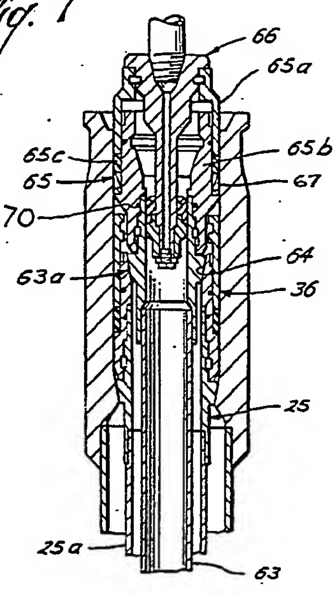


Fig. 7



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Sheet 2

Fig. 5

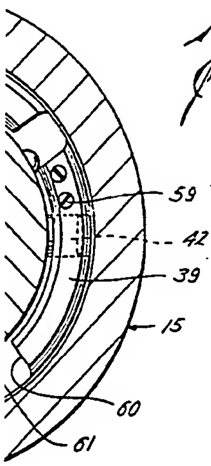
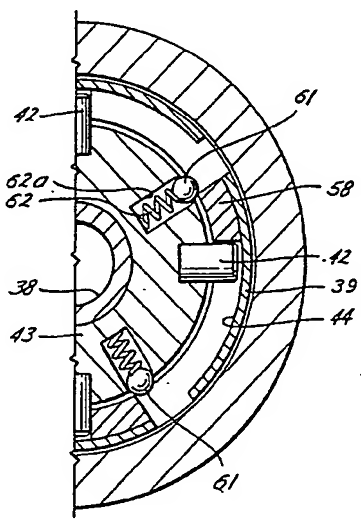
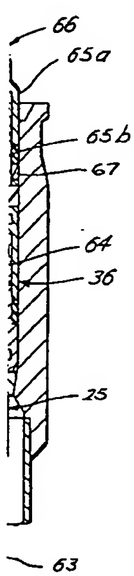


Fig. 6





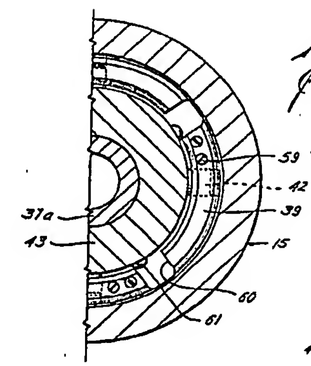


Fig. 5

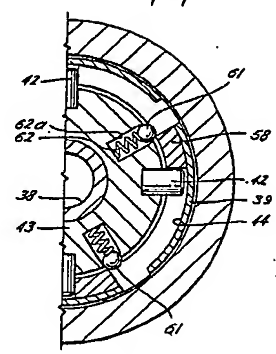


Fig. 6

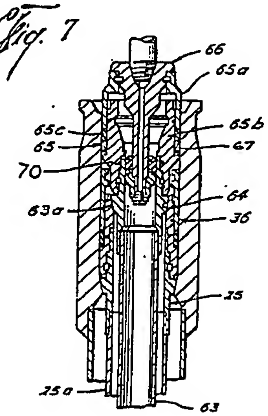


Fig. 7